Dr. D. Vaughan
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DETECTION OF STRYCHNIA AS A POISON,

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INFLUENCE OF MORPHIA IN DISGUISING THE USUAL COLOUR-TEST.

BY

JOHN J. REESE, M.D.,

OF PHILADELPHIA.

[Extracted from The American Journal of the Medical Sciences for October 1861.]

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The progressive increase in the number of deaths, within the last few years, occasioned by strychnia, used either for homicidal or suicidal purposes, is a subject demanding the careful consideration both of the toxicologist and the medical jurist; and every circumstance connected with the detection of this most potent agent cannot fail to interest the medical profession at large.

I have lately had occasion to investigate this subject very closely, in connection with a case of alleged poisoning by strychnia. A man was indicted for the murder of his wife, before the Court of Oyer and Terminer of Perry Co., Pa., at the April term of the present year. The woman died in December, 1860. Although the circumstances of her death were such as to excite suspicion at the time, no examination of the body was made until six weeks had elapsed, when the feelings of the community appear to have become sufficiently aroused to demand an investigation. The body was accordingly disinterred, and the examination was conducted by several respectable physicians of the place. They found the body still in a good state of preservation, but very rigid. The lungs were deeply engorged with dark blood, which escaped very copiously when they were cut into. The heart was healthy (although it was attempted to prove subsequently in the defence, that the woman was subject to cardiac disease); it was not empty and contracted, as has sometimes been found under similar circumstances, but it contained a considerable quantity of blood. The brain and spinal marrow were not examined, which is to be regretted, inasmuch as these organs are almost uniformly found congested in cases of death resulting from strychnia. The stomach and a portion of the small intestine were carefully tied, and along with the adhering pancreas, were reserved for a chemical analysis. The removed viscera were brought to Philadel-

phia, and I was requested to undertake the examination, which I commenced just eight weeks after the death of the subject.

I found the stomach but comparatively little changed in appearance, considering the length of time elapsed since death. Its lining membrane was healthy, with the exception of a few dark congested spots. There was neither ulceration, softening, nor erosion of the membrane. The same is true also of the fragment of intestine examined. The contents of the stomach and bowel consisted of about four or five ounces of a thick, brownish, homogeneous fluid.

The chemical examination was conducted with scrupulous care. I made *three* separate analyses—one of the contents of the stomach, one of the contents of the intestine, and a third of the tissues themselves; and each one of these was repeated a second time, so as to avoid all possible error. Yet I entirely failed to detect any evidence of the presence of strychnia, either by the bitter taste of the final extract, or by the very delicate *colour-test* employed.

Now, inasmuch as all the *moral* circumstances connected with this case (as elicited in the subsequent trial), as well as the symptoms attending the woman's death, clearly pointed to poisoning by strychnia, I felt desirous of ascertaining if there was any adequate cause which might satisfactorily explain the failure to detect the poison. In the first place, as is very well known, it is, as a general rule, more difficult to detect the presence of an *organic* poison in the stomach than of a mineral poison. For example, arsenic, antimony, or mercury may almost always be discovered with absolute certainty, even long after death, provided the individual had not survived long enough after taking the poison to allow of its total elimination from the system—a period averaging about two weeks. This is not the case, however, with an *organic* poison, either vegetable or animal. The alkaloids, especially, are known to undergo very rapid absorption from the stomach, and elimination from the blood. In their passage through the system, it is quite reasonable to suppose, from their complex nature, that they follow the general law of chemical decomposition; and that, unless searched for very soon after administration, the likelihood of detecting them would be extremely small. Now the case before us was just of such a character. The individual survived five or six hours after swallowing the alleged poison—an unusual length of time; again, a period of eight weeks elapsed after death before the chemical examination was undertaken. And we have the highest authorities for believing that organic poisons do undergo change in the body, *after* death.

There was, however, one other circumstance connected with the case, which to my own mind was of especial interest and importance—namely, the fact that the woman had taken, just before death, by the advice of her medical attendant, *a quarter of a grain of morphia* with a little ipecacuanha; but that she did not vomit. Now, the value of this fact is just

this: it has been ascertained that the presence of morphia and other substances has the effect of disguising, and entirely neutralizing the usual *colour-test* used for detecting strychnia; so that, although the latter might be undoubtedly present, yet, if morphia were also present at the same time, the strychnia could not be discovered. It will be readily admitted that this is a point of the extremest importance to be settled by the chemist, in medico-legal researches. It is one to which no very especial attention has hitherto been given. It is merely mentioned as a casual fact in the various works on toxicology, but the only actual experiments recorded, to my knowledge, are those published by Dr. T. G. Wormley, in the *Ohio Med. and Surg. Journal*, for September, 1859, in which it is stated that, when the morphia *exceeds* the strychnia in quantity, the possibility of discovering the latter by the colour-test diminishes. The author himself lays no particular stress upon the fact. I accordingly undertook a series of experiments for the purpose of more accurately determining, if possible, this very important subject, and with the following results:—

Experiment 1. One-tenth of a grain of pure strychnia was added to about twelve ounces of water, into which were put several ounces of fresh beef, finely cut up, together with some starch, a little common salt, and a few drops of acetic acid; (the object being to represent, as closely as possible, the contents of a human stomach after a meal.) The whole was digested on a sand-bath for 12 hours at a moderate heat. It was then strained, pressed and filtered; and afterwards evaporated down to a very small bulk. It was next divided into two separate portions, each of which, of course, would contain the $\frac{1}{20}$th of a grain of strychnia. One of these portions was treated after the process known as Graham and Hoffman's (the alkaloid being removed by animal charcoal, and finally extracted by ether). Here, a drop or two of the ethereal solution, representing about the 1-40,000th to the 1-50,000th of a grain, gave distinct evidence of strychnia by the usual colour-test. The second portion of the evaporated solution was divided into two parts, each of which would of course contain the $\frac{1}{40}$th of a grain of the alkaloid. The first of these was treated according to the process of M. Staäs, in which ether is used as the ultimate solvent: and the second part after the process of Mr. Prollius, in which the ultimate solvent was chloroform. In both instances I obtained the most satisfactory proofs of the presence of strychnia; operating upon a single drop of the fluids—which would represent, certainly, not over the 1-100,000th of a grain of strychnia.

Expt. 2. This was a repetition of the former experiment, except that the quantity of strychnia used was much smaller—only the $\frac{1}{100}$th of a grain. After treatment by Staäs' process, and on concentrating the ultimate ethereal solution, the presence of strychnia was manifested both by the colour-test, and by the bitter taste of the extract. Here, the quantity of the poison operated upon was less than the 1-100,000th of a grain.

Expt. 3. This was an exact repetition of Expt. 2, except that to the $\frac{1}{100}$th of a grain of strychnia, three times that quantity of morphia ($\frac{1}{3}$d of a grain) was added. On treating this by Staäs' process, as in the preceding cases, I could not discover the slightest trace of either strychnia or morphia, even after the ultimate ethereal solution was concentrated to a very small bulk by evaporation.

Now, from the first two experiments just mentioned, in which the processes used were the precise counterparts of those employed in the analysis of the stomach, I think I am justified in concluding that these processes were extremely delicate and reliable: and that if the poison had been present, even in so minute a quantity as the $\frac{1}{100}$th of a grain, it ought to have

been discovered, unless its presence had by some means been concealed. The *third* experiment would seem to prove, most unequivocally, that morphia, when present in excess, along with strychnia, has the property of so concealing the latter, as to render it impossible to detect it by the usual chemical test.

Expt. 4. This was also a repetition of Expt. 2, except that to the $\frac{1}{100}$th grain of strychnia, the $\frac{1}{50}$th grain of morphia was added instead of the $\frac{1}{33}$d—or double instead of treble the quantity. Here, likewise, there was a total failure to discover the poison.

Expt. 5. This was a repetition of the last, except that only $\frac{1}{100}$th grain of morphia was added to the $\frac{1}{100}$th grain of strychnia, or an equal portion. The result here was that I obtained the faintest possible evidence of the presence of strychnia, and only after repeated trials.

From these last experiments I think we may conclude that *the influence of Morphia in preventing the detection of minute quantities of Strychnia, in the presence of an organic fluid, depends upon the relative quantity of the two alkaloids;—the Strychnia being not discoverable when the Morphia is in excess, and barely discoverable when in equal quantity.*

I next instituted another set of experiments, with a view of ascertaining the effect of morphia in disguising the presence of strychnia *in perfectly pure solutions*—that is, entirely free from all organic mixtures. I purposely made use of extremely minute quantities of these substances, inasmuch as I was desirous of drawing correct inferences, which might be applicable in testing for the smallest quantities of the poison existing in the stomach. The general results of these experiments are interesting, and somewhat curious, as exhibiting the fact, that not only is the difficulty of detecting strychnia greatly increased by increasing *the proportion* of morphia, but that the *actual amount* of strychnia that can be discovered is nearly in an inverse ratio with the amount of morphia used. For instance, when the proportion of the two alkaloids was *one to one*, I was able to detect as minute a quantity as the 1-500,000th of a grain. When the proportion was one of strychnia to two of morphia, the smallest discoverable amount was about the 1-300,000th of a grain. When the proportion was *one to three*, the quantity discoverable was the 1-150,000th of a grain. When *one to four*, the minimum quantity was about the 1-100,000th of a grain. When *one to five*, the minimum quantity was 1-80,000th of a grain. When the proportion was *one to ten*, the smallest quantity discoverable increased to the 1-10,000th of a grain: and when the proportion was as high as *one to twenty*, the quantity rose to the 1-5,000th of a grain. Beyond this I did not pursue my experiments, as I was satisfied as to the general results. Dr. Wormley's observations, as recorded in the paper already quoted, go to show that the detection of strychnia, in the presence of an excess of morphia, is really more difficult when the amount of both alkaloids is very large, than when it is comparatively small; thus, he states that, when he experimented on one part of strychnia with one-and-a-half

of morphia, in a large quantity, "the reaction" of the colour-test "is just perceptible." One part with two of morphia gives "but a mere trace" when the quantity of strychnia is as large as the $\frac{1}{30}$th of a grain. One part with three of morphia gives "no reaction" when the quantity is large.

But the important point was to determine how a quantity, almost infinitesimal, might be affected by an amount of morphia, which, though small in itself, yet bore a relatively large proportion to strychnia; just precisely such a state of things as would be likely to be met with in an analysis of the human stomach.

In connection with the foregoing experiments, and with the view of still more closely testing the question of how far the presence of morphia would operate in disguising strychnia, when both had been present in the stomach of a living animal, I administered the poison to three half-grown cats, with the following results:—

Half a grain of pure strychnia was given to the first animal, and in eleven minutes it died in a violent convulsion. The poison was very easily discovered in its stomach, by the usual tests, on the following day. To the second animal a quarter of a grain of strychnia and the same quantity of morphia were given; and, somewhat to my surprise, the animal was deeply convulsed in six minutes, and died very quickly. Here the morphia, so far from counteracting the toxic influence of strychnia (as might have been inferred from its opposite physiological influence), seemed actually to have increased its effects.[1] The stomach of the second animal was likewise examined, but I obtained scarcely recognizable evidence of strychnia, owing doubtless to the influence of the presence of the associated morphia. It will be recollected that the quantity of morphia in this case was just equal to that of the strychnia. To the third animal, the $\frac{1}{20}$th of a grain of strychnia, and the $\frac{1}{10}$th of a grain of morphia (double the quantity) were administered. Convulsions took place in about fifteen minutes, and death in half an hour. The stomach was examined by Staäs' process,

[1] This fact is in accordance with the observation of Bernard, in relation to the effect of the woorara poison not counteracting, but rather increasing the violence of the poisonous action of strychnia, although these two substances, separately, possess such opposite physiological properties—the one being a powerful neurotic excitant, the other an equally powerful depressant. It must be remembered, however, that another high authority, M. Vella (*Comptes Rendus*, t. lx.), makes an opposite assertion to that of Bernard; he contends positively for the antagonism of the two poisons.

The experiments of Drs. Hammond and Mitchell (Experimental Researches on Corroval and Vao, by Wm. A. Hammond, M. D., and S. Weir Mitchell, M. D.; *Am. Journ. of Med. Sci.*, July, 1859), on *corroval* and *vao* (supposed varieties of curara, though differing from it in some physiological points) seem rather to sustain Bernard's views on this point. When either of these substances was administered, along with strychnia, to frogs, they did not neutralize each other, but the peculiar impression of both poisons was produced.

as in the other cases, but with a total failure to detect the poison by the colour-test; although the bitterness of the extract, and its decided action in producing tetanic convulsions in a number of frogs, clearly established its presence.

From all the foregoing experiments, it appears to be conclusively established that morphia does unquestionably possess the power, when present in excess, of completely disguising the usual colour-test of strychnia; and this is emphatically the case when they are associated in organic mixtures, as in the contents of the stomach. Consequently, this fact should always be taken into the account, in medico-legal investigations.

In making the foregoing statement, I regret to find that I differ from so high an authority as Prof. Guy, of King's College, London, who has communicated a valuable paper "On the Colour-tests for Strychnia, &c.," in the *Chemical News* of July 6, 1861. While discussing the question of the effect of the presence of other bodies on the colour-test, this author states, as the result of his experiments made with a great variety of substances—vegetable, animal, and mineral, and including all the matters that would be likely to remain mixed with strychnia when extracted from the contents of the stomach, or from the fluids and tissues of the body—"that the colour-tests are little, if at all, affected by such admixtures."

Now, I feel assured that Dr. Guy could not have experimented on a mixture of strychnia and morphia, or he would have arrived at a different conclusion *in this one instance.* Indeed, he does not enumerate *morphia* among the substances tried by him in association with strychnia, as it probably did not occur to him to employ such a mixture.

So thoroughly was my own mind convinced upon this point, that I felt conscientiously bound to give it in evidence, on the trial of the prisoner, when I was interrogated as to "what causes might prevent the detection of strychnia in the stomach?" As I have already mentioned, the chemical analysis had entirely failed to establish its presence; nor could I discover the slightest bitterness of taste in the ultimate extract. Nevertheless, the prisoner was convicted of murder, probably on the very strong *moral* evidences of his guilt, and was sentenced to execution in spite of the most persistent assertions of his innocence. I have since learned, however, that he subsequently made a full confession of the crime.

It may not be out of place, in this connection, to refer to the most approved methods of testing for strychnia, and also to indicate their relative value. Among the various chemical tests which have, from time to time, been proposed, the only one to which I shall here allude, as entitled, beyond all comparison, to the pre-eminence, is the *colour-test.* This name has been most appropriately given, on account of the beautiful play, or succession of colours, produced when certain oxidizing bodies are brought in contact with strychnia, in the presence of sulphuric acid. The substances usually employed for this purpose are the peroxides of lead and manganese,

bichromate of potassa, ferricyanide of potassium (red prussiate), and permanganate of potassa. While these agents, in conjunction with sulphuric acid, will yield up oxygen to organic substances generally, the alkaloid Strychnia is the only body known which, under the circumstances just mentioned, will exhibit the beautiful *play of colours* already alluded to. When, for example, a small fragment of strychnia is placed upon a white porcelain plate, and a drop of strong sulphuric acid is added, and then a small portion of any of the oxidizing bodies above enumerated is stirred in with it, a beautiful rich violet-blue colour will be given, which very soon changes to a mulberry-purple, and ultimately to a light red tint.

This play of colours, *under the conjoined agency of the oxidizing body and sulphuric acid*, is quite peculiar to strychnia; and, so far as is at present known, it is possessed by no other substance whatever. I will not now stop to discuss the various objections that have, at different times, been urged against the *certainty* of this test. One answer will dispose of them all, namely, that, whilst there are undoubtedly other organic principles, such as morphia, veratria, delphia, salicin, anilin, pyroxanthin, the woorara poison and others, which do yield a colour—sometimes even of a purplish cast, with sulphuric acid *alone*, there is not a single one that will strike the peculiar blue tint with the acid and the oxidizing body *conjointly*. Strychnia alone possesses this peculiarity; and I have no hesitation in regarding this so called colour-test, when carefully applied, as positive and as infallible as any other which the chemist is accustomed to employ, and upon which he ordinarily relies. I am aware that some may be disposed to question the *exclusiveness* of this assertion, and will cite the woorara (curara) poison, and its alkaloid curarina, as an exception. It is true that so distinguished an authority as Dr. Taylor, in the last edition of his work on Poisons (Am. ed., 1859, p. 680), inadvertently makes the statement that curarina resembles strychnia "in giving the peculiar play of colours when treated with sulphuric acid and one of the oxidizing bodies;" but he grounds this statement on a mistranslation from Pelikan, as has been clearly shown by Prof. Guy (vid. *Chem. News*, July 6, 1861). Besides, these two substances differ further in the fact, that whilst sulphuric acid alone gives with curarina (according to Bernard and Reynoso), a rich carmine tint, it causes no change of colour whatever with pure strychnia.

The next point to be briefly noticed is the extraordinary *delicacy* of the colour-test. It is this which gives to it its chief value. As the result of a great number of experiments made for this purpose, I have been enabled to detect with distinctness a smaller quantity than the *half-millionth* part of a grain (the precise amount was the 1-672,000th of a grain); and on some occasions, when experimenting on as minute a portion as the *one-millionth* of a grain, I have obtained a momentary flash of the peculiar blue colour —faint, to be sure, but to the practised eye positive and real.

It is to be understood that these minute quantities of the poison can be

discovered only when it is in the pure state, and free from all other organic admixture. Of course it would be in vain to attempt to detect anything like such infinitesimal portions in mixtures like the contents of a stomach. But as I have already shown, there is no difficulty of discovering as small a quantity as the *one-hundredth of a grain* (and doubtless even less), when diffused in a pint of complex organic mixture.

I will add a few words in relation to the best mode of proceeding, when we desire to test for extremely minute portions of pure strychnia.

A solution is first made of any given quantity—say one-tenth of a grain in a fluidounce of distilled water, with a few drops of acetic acid to insure solution. The number of drops contained in the portion of liquid is to be ascertained by means of a pipette, prepared by drawing out a glass tube to a fine point. The solution may then be diluted to any degree required. One drop of the liquid, representing the ascertained fractional part of a grain, is then to be placed upon a small, perfectly clean white porcelain capsule; and evaporated to dryness, either in the sun or by a very gentle heat. When cold, a drop of pure sulphuric acid is to be placed, by means of a glass rod, on the capsule alongside of the dry spot, but not in contact with it. Next, a small crystal of bichromate of potassa (or, preferably, of ferricyanide of potassium) is to be laid on the dish; after which, a clean, dry and finely-pointed glass rod should be drawn through the drop of acid so as to bring a very little of it in contact with the spot; the little crystal is next to be moved by the rod once or twice over the moistened spot, when there will immediately appear, flashing out, as it were, the characteristic blue colour—more or less transient, according to the amount of the alkaloid present, and passing through the usual tints.

It may appear to some that I have been unnecessarily minute in describing the details of what seems a very simple experiment; but I can assure such that a successful result can only be obtained, when operating upon such extremely small quantities, by the strictest attention to these details. For example, too high a temperature in the evaporation may decompose the minute quantity of strychnia, which, however, must be perfectly dry; again, the sulphuric acid should be pure and strong; for this purpose the drop should be taken by means of a glass rod out of the bottle, and *not dropped* from its rim, as it would, in the latter case, be apt to have become somewhat diluted from moisture absorbed from the atmosphere. Again, the fragment of the crystal used should be very small—one or two lines in dimensions; it should be free from all adherent powder, so as not too soon to dissolve in the acid, and thereby conceal the true colour. For this reason I decidedly prefer the ferricyanide to the bichromate, when manipulating with very minute portions of strychnia: it is much less apt to colour the acid. Lastly, the experimenter must avoid using too much acid; hence the direction to draw only a *portion* of the drop over the strychnia spot, by means of a pointed glass rod. By carefully observing the above direc-

tions, and by a little practice, any one may soon acquire sufficient dexterity in manipulation to bring out very satisfactory results—results far exceeding the most delicate tests usually employed in inorganic chemistry, if we except the beautiful and truly wonderful analyses of Bunsen and Kirchhoff, within the present year, founded on the coloured lines of the spectrum, by means of which even the 1-200,000,000th of a grain of sodium was detected, and which led to the discovery of the new alkaline metals *cæsium* and *rubidium*. This method, however, is optical rather than chemical. Both results exhibit proofs of the extreme divisibility of matter.

Another very beautiful and scientific means of bringing out the colour-test for strychnia has been proposed by Dr. Letheby. (*Lancet*, June 28, 1856.) Ascertaining that it was the nascent oxygen which acted upon the alkaloid and developed the peculiar colours, he employed the agency of galvanism in the place of one of the oxidizing bodies. His method of proceeding is as follows: A drop of the strychnia solution is placed in a cup-shaped depression made in a piece of platinum foil. After evaporating to dryness, the spot is moistened with a drop of strong sulphuric acid. The foil is then connected with the positive pole of a single cell of Groves' or Smee's battery, and the platinum terminal of the negative pole is made to touch the acid. Instantaneously the blue colour flashes out with remarkable beauty and brilliancy. I have repeatedly performed this experiment of Dr. Letheby, and can testify to its good result in portions of *pure* strychnia as small as the 1-50,000th to the 1-100,000th of a grain; but it entirely failed in my hands to detect those *extremely* minute portions which I have before alluded to, as being discoverable by the conjoined use of the ferricyanide of potassium and sulphuric acid. Moreover, I think it open to this objection, especially in the hands of the inexperienced, namely, that all those substances which yield a colour with sulphuric acid *alone*, develop a much richer and deeper colour when subjected to the above-mentioned galvanic test; and this, in some cases, might be readily confounded with an *imperfectly developed* strychnia colour. Thus, in my own experiments with the galvanic test, delphia afforded a rich reddish or purplish-brown tint; veratria, a rich carmine, approaching to violet; salicine, a colour much resembling the last; aconitia, a rich brown; piperine, a rich orange-brown, &c. &c. All of these colours, *including the blue of strychnia*, will change to a deep brown, approaching to black, if the platinum terminal of the negative pole of the battery is kept in contact with the foil *through the acid*. The negative terminal should only touch the drop of acid, and *not* the foil. This circumstance alone is, I think, calculated to detract from the value and certainty of what otherwise is a beautiful and scientific test. Moreover, I was unable to succeed any better by this means, in discovering small quantities of strychnia when combined with an excess of morphia, than when I employed the usual colour-test. In fact, it was much less effective; for I was unable by its

means to discover the 1-20,000th of a grain of strychnia combined with 1-10,000th of a grain of morphia (double the quantity); whilst with the ordinary colour-test, as already mentioned, I could detect as small a quantity as the 1-300,000th of a grain, when associated with double that amount of morphia.

Along with the colour-test, and confirmatory of it, I must not omit allusion to the extreme *bitterness of taste* possessed by strychnia. In truth, it may confidently be asserted to be the *most* bitter substance known—as shown by the following observations, made with a view of comparison with some other well-known bitter articles:—

One grain of strychnia was dissolved in five gallons of water; a single drop of the solution, containing less than 1-500,000th of a grain, afforded a distinct bitter taste.

One grain was dissolved in ten gallons of water; a few drops held in the mouth for a moment or two produced a very perceptible bitter taste.

A third experiment still more strongly illustrates this property: A solution was made of one grain in twenty-five gallons of water; here, one drop represented less than the 1-2,500,000th of a grain. On rinsing the mouth forcibly with a portion of this solution, a faint though distinct bitter taste was perceptible. In fact, so intense and permanent is the bitter taste of strychnia, that this quality may be regarded as affording a good corroborative proof of the presence of the poison. So true is this, that I doubt if it is possible to obtain the *colour-test* in any case where the evaporated extract affords no bitter taste. Hence, its great value in medico-legal researches.

The results of experiments on other bitter substances are as follows:—

Extract of quassia came next to strychnia; its limit was a drop containing 1-358,000th of a grain—equivalent to a solution of one grain in three and a half gallons.

Carbazotic acid, aloes, and *extract of colocynth* were next in order; they all possessed about an equal degree of bitterness. One drop of a solution containing a grain to two gallons, and representing a little over the 1-200,000th of a grain, afforded a slight bitter taste.

Sulphate of quinia yielded a perceptibly bitter taste in as small a quantity as the 1-125,000th of a grain—equivalent to a solution of one grain in a little over a gallon.

Picrotoxine was slightly inferior to quinia in bitterness; the 1-100,000th of a grain may be taken as the appreciable limit.

The *salts of morphia* were vastly inferior to any of the foregoing in point of bitterness; the limit being the 1-7,000th of a grain—equivalent to a solution of a grain in half a pint of water.

I also performed a series of experiments with a view of determining the comparative value of the so-called *physiological* or *frog-test,* first noticed by Dr. Marshall Hall. There are several methods of employing this test; one

is to immerse the body and hind legs of the frog in the strychnia solution; when, after a shorter or longer time, depending upon the strength of the solution and the size of the animal, tetanic spasms will be produced, owing to the poison absorbed. A second method is to inject a few drops of a solution of known strength into the subcutaneous tissue of the thorax or abdomen of the animal. A third mode is to inject a similar solution into the stomach through the œsophagus. Either one of these methods will afford satisfactory results. The first one, or that by cutaneous absorption, was, I believe, that adopted by the distinguished discoverer; and as I found it a very convenient one, I also followed it in my own experiments.

The extreme susceptibility of the frog to the influence of strychnia is truly remarkable. Long known as affording us one of the most delicate indications of the galvanic current, so as to be esteemed pre-eminently *galvanoscopic*, this little animal would appear to be no less sensitive to the action of the subtle poison now under consideration, so that it merits with equal propriety the appellation of *strychniascopic*.

In experimenting with frogs with a view to determine the presence of strychnia in minute quantities, it is advisable to make use of very small animals—those, for example, whose bodies measure from an inch to an inch and a quarter in length, and which would weigh from twenty-five to fifty grains. The simple method which I adopted, and which I found to answer extremely well, was to put a small quantity of the strychnia solution—about a fluidrachm, or even half that quantity—into a deep conical glass vessel, such as an ordinary pint graduate measure, and then place the frog at the bottom. The shape of the jar insures the required immersion of the hind legs and body of the animal in the liquid, while the head remains perfectly free for breathing. Any efforts to escape are usually prevented by the sides of the vessel; or, if necessary, it should be pushed down again into the fluid—the object being to insure continuous contact. The subjoined experiments were undertaken by me with the twofold view first, of comparing the value of the frog-test with the other strychnia tests; and secondly, of ascertaining if the presence of morphia would produce any modification of the usual effects of strychnia on the frog.

Experiment 1. A frog weighing 45 grains was put into a solution of strychnia, one drop of which contained the 1-13,500th of a grain—(equivalent to about one grain in twelve fluidounces.) Convulsions were produced in four minutes.

Expt. 2. A solution of one-half the strength of the preceding (or one grain in twenty-four fluidounces) affected a frog weighing 40 grains in five minutes.

Expt. 3. A solution of one-half the strength of Expt. 2 (or one grain in forty-eight fluidounces, or three pints) produced spasms in a frog weighing 28 grains in five or six minutes.

Expt. 4. A solution of one-half the strength of the last (or one grain in six pints) affected a frog weighing 35 grains in eight minutes. In this case the animal was immersed only five minutes, and subsequently recovered. In the former instances they very soon died.

Expt. 5. A solution of one-half the strength of that used in Expt. 4 (or one grain in twelve pints) produced the tetanic spasms in fifteen minutes. In this case also the animal recovered.

Expt. 6. A solution of one-half the strength of the preceding (or one grain in three gallons, in which one drop represented the 1,430,000th of a grain) produced no effect on one frog after an immersion of twenty minutes; but in another, weighing 29 grains, after half an hour's immersion, decided convulsions were exhibited, and the animal suddenly died. Beyond this, I did not deem it necessary to proceed in my investigations, fully satisfied with the result; though doubtless a still more minute quantity might be shown to affect a very small animal. It may, I think, be safely affirmed that a solution containing as small a portion as the *half-millionth of a grain to a drop* may thus be recognized.

These experiments, more especially the last, illustrate very satisfactorily the extreme delicacy of the frog-test for strychnia; for certainly only a very minute portion of the poison—an almost infinitesimal quantity—could have been absorbed through the animal's skin, in the limited time mentioned. I will cite one additional experiment, under this head, which, to some, may probably appear still more conclusive:—

The 1-500th of a grain of strychnia was put into the mouth of a middling-sized frog: death took place, preceded by the usual spasms, in about twenty minutes. The abdominal viscera were removed, and treated after Staäs' process. The ultimate ethereal extract was very slightly bitter, but afforded no perceptible colour-test. On dissolving this extract in water, the solution produced the most decided tetanic convulsions on three healthy frogs, averaging 100 grains in weight each. A portion being injected beneath the skin of one, brought on twitchings in four minutes, resulting in death: a second, treated in a similar manner, was convulsed in ten minutes, but recovered: the third was simply immersed in the solution, and a small portion injected into the stomach, with the effect of producing spasms, from which, however, the animal recovered.

As a *corroborative* evidence of the presence of strychnia I should regard the frog-test as one of great importance, and one which ought never to be omitted in medico-legal researches. Taken in conjunction with the delicate colour-test already alluded to, and the bitter taste of the evaporated extract, it affords such overwhelming proof of the presence of strychnia as can admit of no possibility of cavil.

Being desirous, in the next place, of ascertaining if the presence of morphia (which I had found produced such a decided influence on the colour-test) would occasion any modification in the frog-test, I made the following experiments:—

Experiment 1. A frog weighing 29 grains was immersed in a solution containing one grain of strychnia and two grains of morphia in twenty-four fluid-ounces of water. Convulsive movements commenced in four minutes. Here, the proportions were one of strychnia to two of morphia.

Expt. 2. A frog weighing 40 grains, on being immersed in a solution containing half as much strychnia, but twice as much morphia, as in the former experiment (the proportion being one to eight), exhibited spasms in five minutes.

Expt. 3. A frog weighing 100 grains was immersed in a solution containing one grain of strychnia and twelve grains of morphia in forty-eight fluidounces of water. It exhibited the usual tetanic symptoms in fifteen minutes.

Expt. 4. A frog weighing 35 grains was immersed in a solution containing one grain of strychnia and thirty-two of morphia in six pints of water. It was affected with tetanic spasms in twenty minutes; another, rather smaller, was affected in five minutes.

Expt. 5. A cat was poisoned by taking one-twentieth of a grain of strychnia and one-tenth of a grain of morphia (double the quantity): convulsions and

death took place in about thirty minutes. The stomach was, on the next day, analyzed by Staäs' process. The ethereal solution, although concentrated, totally failed to yield the colour-test (as already mentioned), but the extract possessed a slightly bitter taste, and its watery solution produced the most decided convulsions (generally resulting in death), in *eight* distinct frogs, averaging 100 grains each. Some were merely immersed in the liquid; to others, it was administered either by injecting into the stomach, or under the skin.

It is abundantly evident from the above experiments, that very little, if any, effect is produced by morphia in modifying the influence of strychnia upon frogs; consequently, the presence of morphia, although most seriously interfering with one of our means of detecting this poison, viz., the *colour-test*, most fortunately produces no impression on the almost equally delicate *frog-test*.

Since making these very delicate experiments with frogs, I have regretted that I was unable to apply this test in the poison case mentioned at the commencement of this paper; but I was unfortunately unable to procure any frogs of the proper kind in the winter season, when the examination was made.

Before concluding this already lengthy paper, I will add a word or two in reference to the *microscopy* of strychnia—a subject which, I believe, has not heretofore been particularly noticed. Having ascertained the extreme delicacy of the other modes of testing for this substance, it occurred to me to examine minute portions by means of the microscope; and the results obtained were exceedingly beautiful and satisfactory. I have succeeded best by evaporating a drop of a solution in pure water, of known strength, on a glass slide, and subjecting it to the field of a good instrument. The solution must, of course, be perfectly pure, and free from all organic matters. Very satisfactory results may be obtained by using quantities as small as the 1-50,000th to the 1-500,000th of a grain; although even the 1-1,000,000th may easily be recognized. The appearance presented to the eye is that of numerous crystals, some acicular and others stellate and scalloped, intermingled with dentated crosslets; the whole bearing a striking resemblance to the appearance presented by the arborescent crystals of the triple phosphate seen in a drop of evaporated urine.

It is not pretended that we should rely on the microscopic appearance as a test for strychnia *per se;* it can only be employed as a corroborative proof; but its delicacy and its beauty should always justify its employment, so far as practicable; although it must not be forgotten that it is available only when the alkaloid is in a state of purity.